Does Technology Disruption Always Mean Industry Disruption?[1]

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Abstract

In 1997, in his best-selling book *The Innovator's Dilemma*, Clayton Christensen made critical observations about the conditions under which established firms lose market to entrants with disruptive technology. His work became highly influential, making *disruptive technology* a buzz word, "thrown around" by the popular media in contexts far beyond Christensen's original claims. Fearing that such over-zealous use of the phrase could lead to inefficient strategic decisions; in this paper we broaden the research agenda around industrial disruption by asking: *do potentially disruptive technologies always displace the existing industrial order?* We first analyze media sources in conjunction with industrial statistics to demonstrate that several technologies proclaimed by media to be disruptive have failed to displace the industry order. We then offer a general model of industry disruption based upon field research. Our analysis shows that three types of uncertainties – technical, market, and organizational – may explain why such potentially disruptive technologies fail to displace the existing industrial order. Our work should not be misconstrued as a contradiction of Christensen's work. Our general model, perhaps the first differential model of industry disruption contributed to innovation literature, in fact builds upon Christensen's conditions, and argues for broadening the research agenda for understanding industry disruption.

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INTRODUCTION AND MOTIVATION

In 1997, in his work leading up to the best-selling book "The Innovator's Dilemma," (Christensen 1997) Clayton Christensen made critical observations about the conditions under which established firms lose market to an entrant with what he called *disruptive technology*. In the years to follow, this work became highly influential in managerial decision-making. In the process, however, as it happens with many influential theories, disruptive technology became a buzz word, being "thrown around" in contexts that often go far beyond the claims Christensen originally made.

Christensen's original arguments, as summarized from the more academic references (Christensen 1992; Christensen 1992; Christensen and Rosenbloom 1995; Christensen, Suárez et al. 1996) rather than the more popular paperbacks (Christensen 1997; Christensen and Raynor 2003), were that understanding when an entrant might have an advantage over the incumbent requires understanding of three interlocking forces: technological capability (incremental versus radical, or architectural versus component innovations (Henderson and Clark 1990)); organizational dynamics (capability enhancing versus capability destroying innovations (Anderson and Tushman 1990)); and the third force – value network – the context within which the firm identifies and responds to customers' needs, procures inputs and reacts to competitors (Christensen and Rosenbloom 1995). Further, he argued that firm's competitive strategy, and particularly its past choices of markets to serve, determines its perceptions of economic value in new technology, and in turn shapes the rewards it will expect to obtain through innovation.

Christensen also documented several industries with successful disruption including disk drive industry where giants like IBM were the victims, excavator manufacturing industry where the hydraulic excavators wiped out the entire population of mechanical excavator manufacturers, and steel manufacturing where mini steel mills disrupted vertically integrated steel mills (Christensen 1997).

The above pattern Christensen identified is simple to understand and quite pervasive in many industries. What is misleading, however, is the loose and opportunistic use of the term "disruptive technology" by the popular media and experts. As we will demonstrate, technologies that the media prematurely called as "disruptive technology" often failed to disrupt the existing industrial order.

Should such an over zealous use of the phrase "disruptive technology" bother us? On one hand, the threat of disruption makes incumbents paranoid about losing the market, while making new entrants hopeful of inventing the next disruptive technology. Arguably, such hopes and fears create more competition in the market place. On the other hand, however, incorrectly calling every technology disruptive, could lead to inefficient strategic decisions by managers and policymakers.

The purpose of this paper is to investigate the question: *do potentially disruptive technologies always displace the existing industrial order?* In other words, under what conditions the industry disruption is more or less likely given a potentially disruptive technology. Such an investigation must not be misconstrued as a contradiction of Christensen's work. The idea here is to embed his work in a broader context, so as to build upon it, hoping that such an exercise will expand our understanding of the conditions for industry disruption.

The remaining of the paper is organized as follows. We begin with a general survey of popular media's usage of the phrase "disruptive technology." We show that in two fast clock speed industries – computers and telecommunications – the technologies media proclaimed as disruptive eventually failed to disrupt the industry structure. To study the reasons for such an outcome, in the following section we develop a general model of industry disruption. In the results section we analyze the model to understand the conditions under which a technology disruption does not lead to industry disruption. Finally, we will discuss some results and conclusions and see how the conclusions might hold.

MISPERCEPTIONS OF "DISRUPTIVE TECHNOLOGY"

Let us begin by examining the popular media for technologies that were declared as disruptive technologies subsequent to Christensen's best selling book *The Innovator's Dilemma*. Table 1 shows the technologies the New York Times identified as "disruptive technology" anytime before March 2008.

Potentially Disruptive Technology	Industry[2]	Source
Organic LED	Electronic Equipment Manufacturers	(Eisenberg 1999)
Nano science in chip manufacturing	Semiconductor Equipment	(Markoff 1999)
Open Source Software	Computers: Systems Software	(Lohr 2000; Lohr 2000)
Online Book Stores	Retail, Internet Services	(Gould 2000)
e-Port (Internet-based Advertising)	Advertising, Internet Services	(Kane 2000)
Digital Photography	Photographic Products	(Legomsky 2000)
Gigabit Ethernet	Communications Equipment	(Markoff 2000)
Online Investment Firms	Investment Banking and Brokerage	(McGEEHAN and Hakim 2000)
Online Journals	Publishing	(Nagourney 2001)
WiFi Mesh Networks	Wireless Telecommunications Services	(Markoff 2002)
Segway Scooter	Automobile Manufacturer	(Riordan 2002)
Alternative Energy - Solar, Biomass, Wind, Hydrogen	Oil and Gas Exploration and Services, Electrical Utilities	(Cortese 2003)
P2P Service Providers	Telecommunications Service	(Fallows 2004)
P2P File Sharing	Movies and Home Entertainment	(Varian 2005)
Online Shopping	Retail	(Lohr 2005)
Online Book Content	Publishing	(Peck 2006)

[2] We have used the industry classification provided by The Global Industry Classification Standard (GICS), a collaboration between Standard & Poor's and Morgan Stanley Capital International, to classify the potentially disruptive technologies.

Online Commodity Futures Exchange	Commodity Futures Exchange	(Bajaj 2006)
YouTube (Political Advertising)	Advertising	(Carr 2006)
YouTube (Video Content Distribution)	Movies and Entertainment, Publishing	(Carr 2006)
Paint Films	Auto Parts and Equipment	(Brooke 2007)
Advertising using Social Networks	Advertising	(Stelter 2008)

Table 1 Technology identified as "disruptive technology" in popular media (The New York Times)

Just a glance at Table 1 indicates that several technologies listed as potentially disruptive represent significant innovations; for example, open source software, digital photography, online shopping, and P2P file sharing. These are technological paradigms that have come to stay. However, the question we are interested in is: have these technologies displaced the existing industrial order?

To answer the above question, we first restrict our analysis to two fast clock speed industries – computers and telecommunications industries. We make such a choice consciously, as in these industries the change is rapid and provides better opportunity to study changes in the industry structure in a short period of time. Going forward, in this paper we will study three potentially disruptive technologies: Open Source Software (Computer Systems Software Industry), WiFi Mesh Networks (Wireless Telecommunications Services Industry) and P2P Service Providers (Telecommunications Service Industry).

In Christensen's case of disruptive technologies, the disruption occurs when the entrant's technology has lower price and lower primary performance, but a great promise of ancillary performance in the future (Christensen 1997) when compared to the incumbent's technology. The primary performance constitutes the features of the incumbent's technology that the customers care the most about. The ancillary performance refers to the additional benefits the new technology is likely to offer. Table 2 summarizes Christensen's conditions for disruptive technology.

Firm	Price	Primary Performance	Ancillary Performance (future)
Incumbent	High	High	Low
Entrant	Low	Low	High

Table 2 Christensen's conditions for disruptive technology

We must first ask the question: do technologies we propose to study fit Christensen's conditions listed in Table 2? For an entrant technology to fit Christensen's conditions it must have lower price, lower primary performance and higher future ancillary performance when compared to the incumbent. Table 3 shows that all the other three technologies we consider fit Christensen's conditions.

Potentially Disruptive Technology (Table 1 column 1)	**Price compared to Incumbent**	**Primary Performance compared to Incumbent**	**Ancillary Performance (future) compared to Incumbent**
Open Source Software	(Low) Many open source software are free	(Low) Initially, most open source software have poor reliability and ease of use. They also have more bugs.	(High) Open source software has quick turnaround on bug fixing and allows users to modify the code to their needs
WiFi Mesh Networks	(Low) Cheaper to build and operate than wireless networks	(Low) Lower mobility than wireless networks	(High) - Better speed in most places compared to wireless networks - Ability to switch between wireless and wired networks
P2P Service Providers	(Low) Many P2P Services such as Skype, IM are free	(Low) Less reliability and ease of use compared to telephony or television	(High) - Voice, Text, Video convergence - File sharing

Table 3 Potentially disruptive technologies in computers or telecommunications industry and the their fit with Christensen's conditions

We now come to our main question: do technologies (listed in Table 3) that fit Christensen's conditions displace the existing industrial order? To investigate this question, we compare the industrial order pertinent to each potentially disruptive technology from the year 2000 with that in 2007. One might question the choice of the two years; particularly from the perspective that the WiFi Mesh Network and P2P Service Providers did not quite exist in the year 2000. We would argue that the ideas did exist in other shapes or forms then, only that today they have acquired new names. Table 4 shows the analysis.

Potentially Disruptive Technology	**Industrial Order in 2000**	**Industrial Order in 2007**	**Key Observations**
Open Source Software	Top Software Suppliers (S&P 2000) 1. Microsoft 2. IBM 3. Computer Associates Int'l 4. Oracle 5. HP 6. SAP 7. Sun Microsystems	Top Software Suppliers (S&P 2007) 1. Microsoft 2. IBM 3. Oracle 4. SAP 5. Symantec 6. HP 7. EMC	**No industry disruption** • Microsoft Windows controlled 90% of the operating systems market in 2000 and continues to do so in 2007 • Open source operating systems such as Linux still

	8. Unisys 9. Compaq Computers 10. Novell	8. CA 9. Adobe 10. Fujitsu	holds low single digit penetration worldwide (S&P 2007)
WiFi Mesh Networks	Top Mobile Operators (S&P 2000) 1. Verizon 2. SBC/Bellsouth 3. Others 4. AT&T Wireless 5. Sprint PCS 6. Nextel 7. AllTel 8. VoiceStream Wireless	Top Mobile Operators (S&P 2007) 1. AT&T (after Bellsouth acquisition) 2. Verizon Wireless 3. Sprint Nextel 4. T-Mobile 5. Alltel 6. US Cellular 7. Leap Wireless 8. Dobson Communications	**No industry disruption** • US has 65000 WiFi Hotspots • Incumbents like AT&T and T-Mobile own 20000 Hotspots (1/3rd of the US total) • Handset Incumbents like Nokia, Samsung, Panasonic and (in the US) an entrant Apple Inc. lead the Wireless/WiFi dual phone market (S&P 2007)
P2P Service Providers	Long Distance Call Providers (S&P 2000) 1. AT&T 2. WorldCom 3. Others 4. Sprint	Leading Broadband Providers (S&P 2007) 1. AT&T 2. Comcast 3. Verizon 4. Time Warner 5. Charter 6. Qwest 7. Cablevision 8. Embarq 9. Windstream 10. Insight	**Major industry changes** **Early to predict disruption** • Telecommunications Access and Service has undergone a rapid change in the industry structure • The change is more broadly affected by the increasing processing speed and the Internet penetration • Incumbents such as AT&T and Verizon are still big; some through mergers and acquisitions • The P2P Service itself is successful in some economies like Japan/Korea, but slow in others

Table 4 Potentially Disruptive Technologies and the Industrial Order

Table 4 shows that Open Source Software and WiFi Mesh Networks have failed to displace the existing industrial order so far. In the case of Open Source Software, the paradigm has steadily gained market share, but the total market it captures is rather small. More curiously, in the case of WiFi Mesh Networks the incumbents of wireless telecommunications service, such as AT&T and T-mobile, have emerged as leaders in the new technology market. Finally, the case of P2P Service Providers is still open. Many forces are at play here. First, there is the shift from the traditional telephone and television networks to the more Internet-based services using cable or digital subscriber line (DSL) broadband. Then, there is the ever increasing computing power and the rise of the World Wide Web. The industrial order in this case is changing rapidly, but its early to say if the incumbents are losing.

So, what preserves the industrial order despite the technological breakthrough in the above cases? We contend that there are three types of uncertainties at work: technological, market and organizational. First, the nature of technology determines how quickly incumbents and entrants can build primary or ancillary performance. Next, the market characteristics such as network effect and switching costs (discussed later) determine the technology consumers purchase and stay with. Finally, the organizational factors determine how quickly incumbents and entrants respond. To help us understand the effects of these factors, in the following section we present a general model of industry disruption, embedding in it the Christensen's conditions.

A GENERAL MODEL OF INDUSTRY DISRUPTION

Let us now build a more general model of industry disruption. The goal here is to build a model where consumers choose between the incumbent and entrant technology, where the entrant technology meets Christensen's conditions shown in Table 2. Further, we want to expand the model to examine how the nature of technology, market conditions and organizational factors affect the outcome. The basic reference mode that Christensen's conditions generate is shown in Figure 1 (Christensen 1992). A successful model must generate this reference mode as its base case.

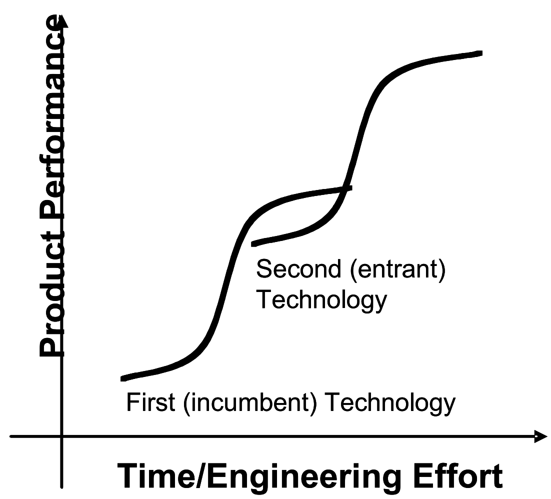

Figure 1 The disruptive technology S-curves

Such a model is akin to behavioral game theory model, where incumbent and entrant firms play a dynamic game of incomplete information for multiple rounds (Gibbons and National Bureau of Economic Research. 1996). To understand the firm's behavior and derive the behavioral rules, we have interviewed two incumbent and two entrant firms. The model explores: (1) how incumbents diversify resources to mitigate a potential disruption, and (2) how entrants focus their resources, and (3) how the market conditions influence the consumer choice.

Assumptions and Model Structure

Figure 2 shows the model boundary diagram. Endogenous to the model are the consumer preference sector and the corporate strategy sector. The consumer preference sector contains the dynamics of how consumers select between the incumbent's or entrant's product based on the product attractiveness. Also, included here are the dynamics of switching from one product to another. The corporate strategy sector has the dynamics of how incumbent's and entrant's allocate resources to attain the desired price, primary and ancillary performance for their products. Exogenous to the model are the cost, primary and ancillary performance acquisition delay. The performance acquisition delays are exogenous as they depend upon the nature of technology. Capacity dynamics are excluded from the model, as our interest here is not the boom and bust dynamics.

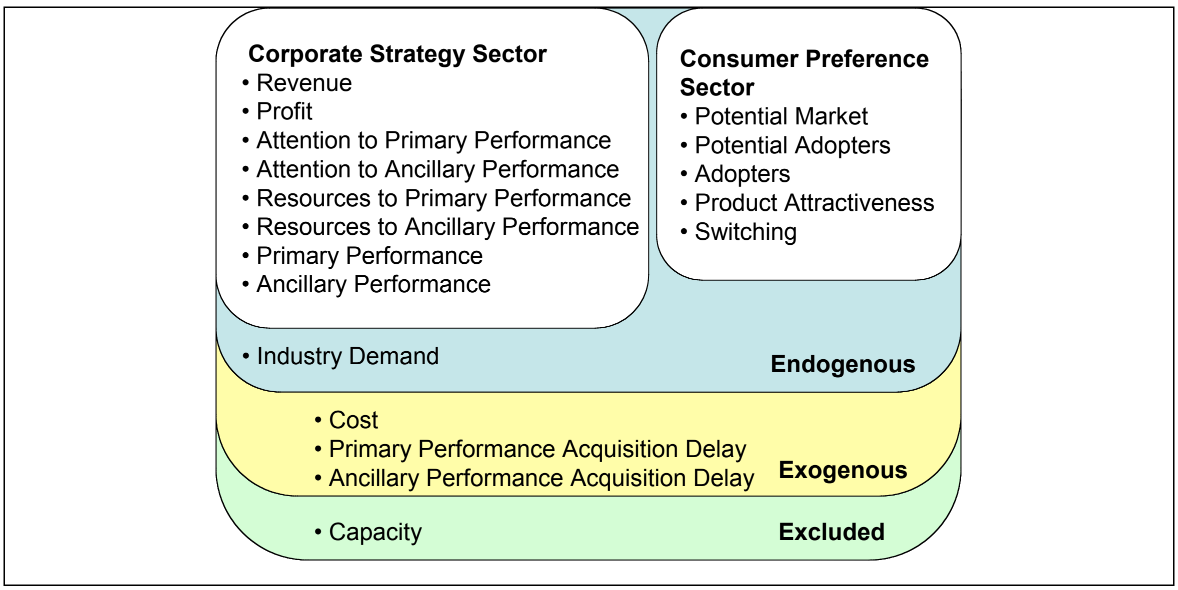

Figure 2 Model Boundary Diagram

The model consists of two firms: one incumbent and one entrant, representing an aggregated view of each type of firm in the industry into a single firm of each type. The model is run for 20 years. This duration might seem long, but if you think about technological paradigms instead of individual firms, it is reasonable. The incumbent enters at year 0. The entrant enters at year 6, essentially, after the incumbent has captured the entire market share.

As shown in Figure 3, consumers go from the potential market to the pool of potential adopters. Firms compete for potential adopters. The number of potential adopters is determined by the industry demand using a standard formulation for industry demand (Sterman, Henderson et al. 2007). A standard Bass Model (Sterman 2000) is used for adoption.

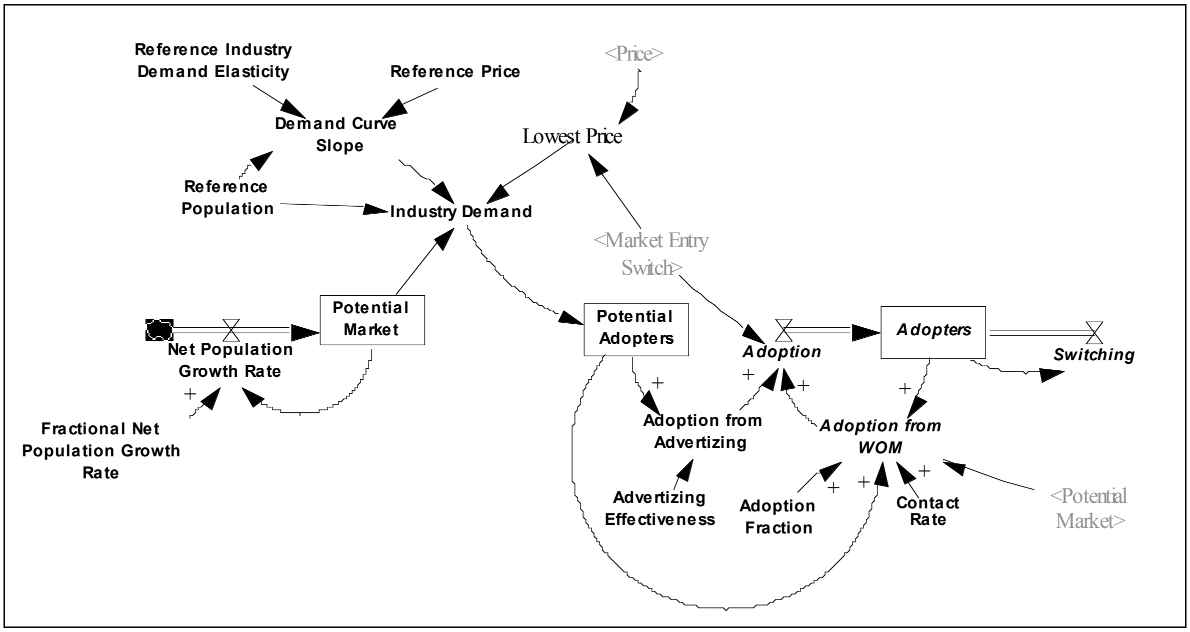

Figure 3 Adoption using industry demand

Adopters select from incumbent's or entrant's product based on their product attractiveness. The consumer (adopter) choice is formulated using a standard logit choice model ((Sterman, Henderson et al. 2007), (Wooldridge 2006)). As depicted in Figure 4, the product attractiveness depends upon four factors: installed base, primary performance, ancillary performance and price. The firm's adopter base grows with its installed base (Loop R1 – Network Effect) and other factors that contribute to product attractiveness. However, two factors constrain or counter this growth: market saturation (Loop B1) and switching to competitor's product (Loop B2).

The model is initialized with incumbent and entrant that look like the base case in Table 2. In other words, the entrant has lower (half the) cost base, and hence the price, as compared to the incumbent. The entrant has lower (half the) initial primary performance than the incumbent, and higher (double the) initial ancillary performance than the incumbent.

The firms are endowed with an equal total attention (or resources) that is (are) finite. The firm's resources are assumed to be divided into those focused on primary performance and ancillary performance. When the entrant is not in the market, the incumbent is assumed to be completely invested in primary performance (Loop R2). The incumbent diversifies resources to ancillary performance after the market entry of the entrant. Because the total resources are conserved (Loop R3), investment in ancillary performance – which would be a virtue in the absence of resource constraint – appears like a burden to the incumbent (Loop B3). The incumbent's dilemma becomes: when and how much to diversify to compete with the entrant.

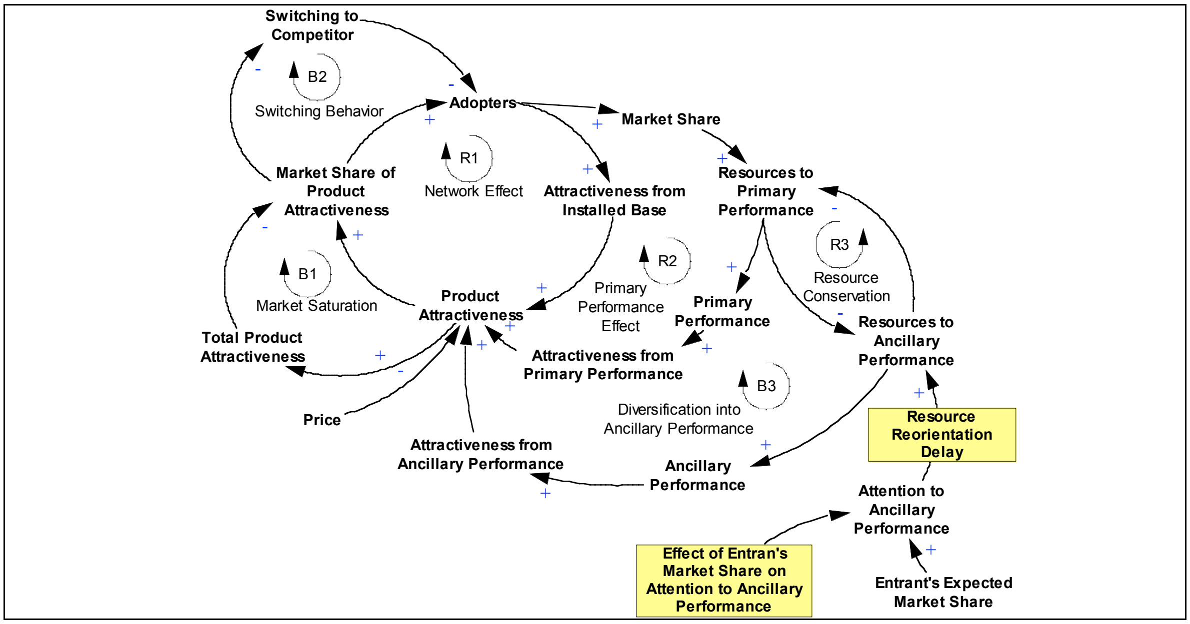

Figure 4 The main Causal structure

Parameters and Key Formulations

In this section we explain the key formulations[3]. We interviewed two incumbent firms (here after, Incumbent A and Incumbent B) and two entrants (here after, Entrant A and Entrant B) to deduce their behavior in the face of the threat of disruption.

Parameters

N Potential Market
PA_x Firm's Potential Adopters [*x = i (incumbent), e (entrant)*]
IB_x Firm's Adopters (Installed Base) [*x = i (incumbent), e (entrant)*]
α_x Firm's Product Attractiveness [*x = i (incumbent), e (entrant)*]
p_x Price [*x = i (incumbent), e (entrant)*]
β_0 Effect of Installed Base on Attractiveness
β_1 Effect of Price on Attractiveness
β_2 Effect of Primary Performance on Attractiveness
β_3 Effect of Ancillary Performance on Attractiveness
PP_x Firm's Primary Performance [*x = i (incumbent), e (entrant)*]
PP_{max} Maximum Attainable Primary Performance
AP_x Firm's Ancillary Performance [*x = i (incumbent), e (entrant)*]
AP_{max} Maximum Attainable Ancillary Perormance
A_i Incumbent's total Attention
A_e Entrant's total Attention
R_i Incumbent's total Resources
R_e Entrant's total Resources

[3] Only those formulations that are new and make a possible contribution to the system dynamics and innovation literature are explained here. The formulations for bass model of diffusion and industry demand are not explained here algebraically, as they are available in the referenced system dynamics literature. A fully documented model is submitted with the paper.

A_i^p Incumbent's attention to primary performance
A_i^a Incumbent's attention to ancillary performance
A_e^p Entrant's attention to primary performance
A_e^a Entrant's attention to ancillary performance
R_i^p Incumbent's resources to primary performance
R_i^a Incumbent's resources to ancillary performance
R_e^p Entrant's resources to primary performance
R_e^a Entrant's resources to ancillary performance
S_i Incumbent's market share
S_e Entrant's market share
T_{pp} Primary Performance Acquisition Delay
T_{ap} Ancillary Performance Acquisition Delay
T_{rr} Firm's Resource Reorientation Time

Consumer Preference

As stated earlier, the consumer choice is formulated using a logit choice function.

$$\log(\alpha_x) = \beta_0 \log(IB_x/IB^*) - \beta_1 \log(p_x/p^*) + \beta_2 \log(PP_x/PP^*) + \beta_3 \log(AP_x/AP^*) \quad (1)$$

Where,
IB^* = Reference installed base beyond which the network effects are strong
p^* = Reference price beyond which products become less attractive
PP^* = Reference primary performance beyond which its effects are strong
AP^* = Reference ancillary performance beyond which its effects are strong

Resource Allocation and Performance

Each firm has a constant total attention (A) or resources (R) that gets divided into Attention to Primary Performance and Attention to Ancillary Performance. Such a resource formulation is motivated by research in strategic management (Gary 2005). Both firms are endowed with a total attention of 1.

$$A_i = 1 = A_i^p + A_i^a \quad \text{for Incumbent}$$
$$A_e = 1 = A_e^p + A_e^a \quad \text{for Entrant} \quad (2)$$

Similarly the Total Resources are divided into Resources to Primary Performance and Resources to Ancillary Performance.

$$R_i = 1 = R_i^p + R_i^a \quad \text{for Incumbent}$$
$$R_e = 1 = R_e^p + R_e^a \quad \text{for Entrant} \quad (3)$$

The entrant's attention and resources to primary and ancillary performance are set to a fixed value for the reason explained below.

$$A_e^p = R_e^p = 0.2$$

$$A_e^a = R_e^a = 0.8 \quad (4)$$

Such an allocation is consistent with the following quotes:

> "After the prototype phase, 80% attention is on developing new features (ancillary performance) and 20% on scale and reliability (primary performance)." CTO, Entrant A

> "New features is our forte. We are not going after the incumbent. The primary performance will come as a byproduct." CEO, Entrant B.

The incumbent on the other hand is paranoid about the disruptive technology and diversifies resources in response to the entrant's position. We have deduced the incumbent's diversification behavior from the following quotes,

> "Incumbent cares about ancillary performance only with: the entry of the non-traditional competitor, and the growth of its market share." Director, CTO Organization, Incumbent A

The formulation for incumbent's attention to ancillary performance is therefore:

$$A_i^a = g(E(S_e)) \quad (5)$$

Where,

$E(S_e)$ = Entrant's Expected Market Share

g = function for Effect of Entrant's Market Share on Attention to Primary Performance.

Entrant's Expected Market Share ($E(S_e)$) is derived using a standard trend function as in (Sterman 2000) pp. 634. The Effect of Entrant's Market share on Incumbent's Attention to Ancillary Performance shown in Figure 5, which is deduced from the quotes:

> "First [when the entrant enters] the question is whether this is a price game or a performance game. Then, at you realize the future is ancillary." Chief Strategist and Architect, Incumbent B

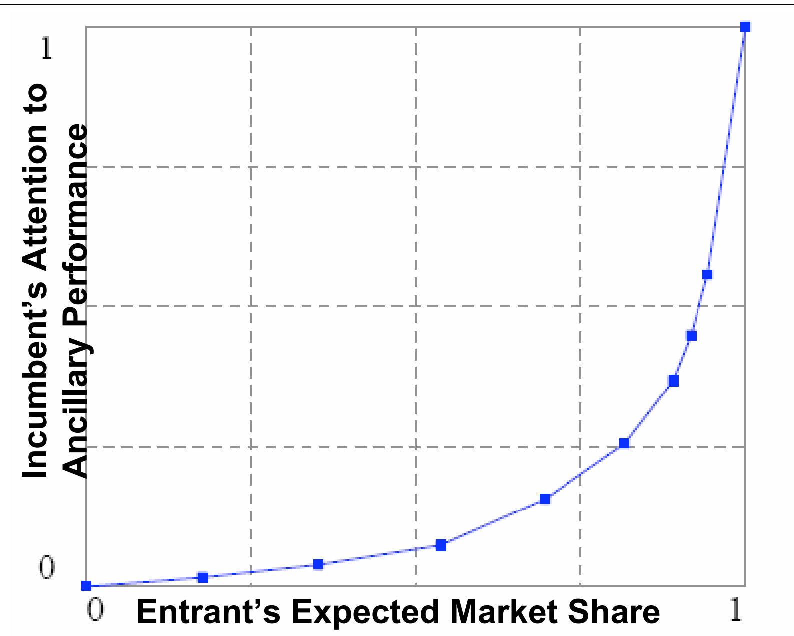

Figure 5 The Effect of Entrant's Market Share on Attention to Ancillary Performance

The incumbent's resource allocation to ancillary performance depends on its attention to ancillary performance, and lags the attention by the Resource Reorientation Time (T_{rr}). This reality is deduced from the following quotes:

> "First you have to write a report, then convince the leadership, and then the people who will work on it." Director, CTO Organization, Incumbent A
>
> "You have to redeploy your best people on it. Your best people are steeped into the old paradigm. Ideally, you want them to lead the new one too, so you have to take them along. This takes time." Chief Strategist and Architect, Incumbent B

This gives us the formulation for Incumbent's Resources to Ancillary Performance (R_i^a).

$$R_i^a = \int (A_i^a - R_i^a)/T_{rr}\, dt \qquad (6)$$

This leaves us with the resource diversification scheme as shown in Table 5.

Firm	**Resources to Ancillary Performance (R_a)**	**Resources to Primary Performance (R_p)**
Incumbent	$R_i^a = \int (A_i^a - R_i^a)/T_{rr}\, dt$ Where, $A_i^a = g(E(S_e))$	$R_i^p = 1 - R_i^a$
Entrant	$R_e^a = 0.8$	$R_e^p = 1 - R_e^a$

Table 5 Incumbent and Entrant's Resource Diversification Scheme

Resource allocation determines how much of the Maximum Attainable Primary Performance (PP_{max}) or Ancillary Performance (AP_{max}) is attained in the given time. The following equation shows the formulation for incumbent's Primary Performance (PP_i).

$$PP_i = \int (C_i^{pp})\, dt \qquad (7)$$

Where,

C_i^{pp} = Incumbent's Primary Performance Change

How rapidly the product's primary performance changes depends upon the resources allocated. For example, in the case of Incumbent, the Change in Primary Performance (C_i^{pp}) is:

$$C_{pp} = R_i^p * (PP_{max} - PP_i)/T_{pp} \qquad (8)$$

Where,

T_{pp} = Primary Performance Acquisition Delay, which is an exogenous value dependent on technology.

Formulations similar to the ones in Equation 7 and 8 exist for incumbent's Ancillary Performance (AP_i), entrant's Primary Performance (PP_e) and entrant's Ancillary Performance (AP_e).

Such a model provides us with the ability to study three types of uncertainties – technological, market, and organizational – highlighted earlier.

RESULTS

In this section we discuss the results; particularly, the conditions under which the technology disruption *does not* cause industry disruption. We begin by understanding the base case behavior. We will then study the outcome under technical, market, and organizational uncertainties.

Base Case Behavior

For our analysis, we will use two base cases: Passive Base Case and Active Base Case. In the *Passive Base Case*, the incumbent does not respond to the entrant's market entry. In other words, it continues to allocate all of its resources to primary performance ($R_i^p = 1$) and no resources to ancillary performance ($R_i^a = 0$). In the *Active Base Case*, the incumbent does respond to the entrant by reallocating its resources. In both cases, the network effects are turned off. Figure 6 shows the adoption for passive versus active base case[4]. It is important to note that Figure 6 generates the disruptive technology S-curves shown in Figure 1.

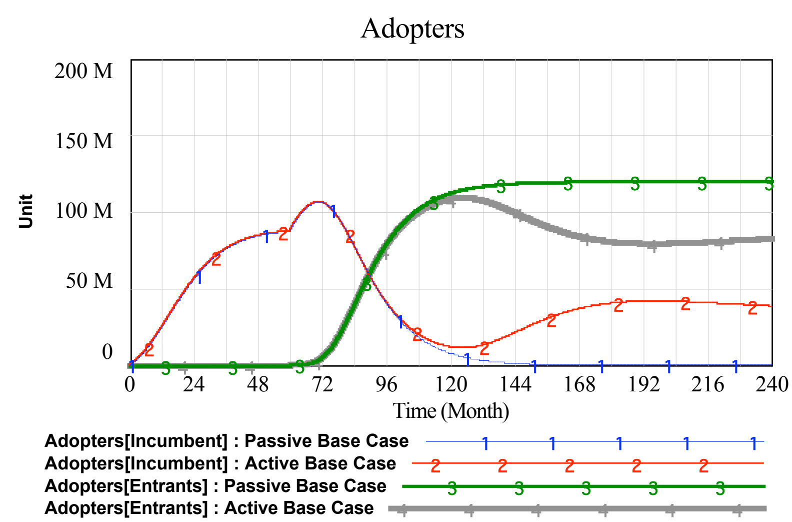

Figure 6 Passive vs. Active Base Case: Adopters for each firm

Figure 7 shows the market share view of the two base cases. In the Passive Base Case the incumbent does not relocate resources and relinquishes the entire maker to the entrant. In the Active Base Case, we see that the incumbent regains some market share to end up in a different equilibrium.

[4] Model runs can be reproduced by using the instructions in Appendix A (at the end of this paper)

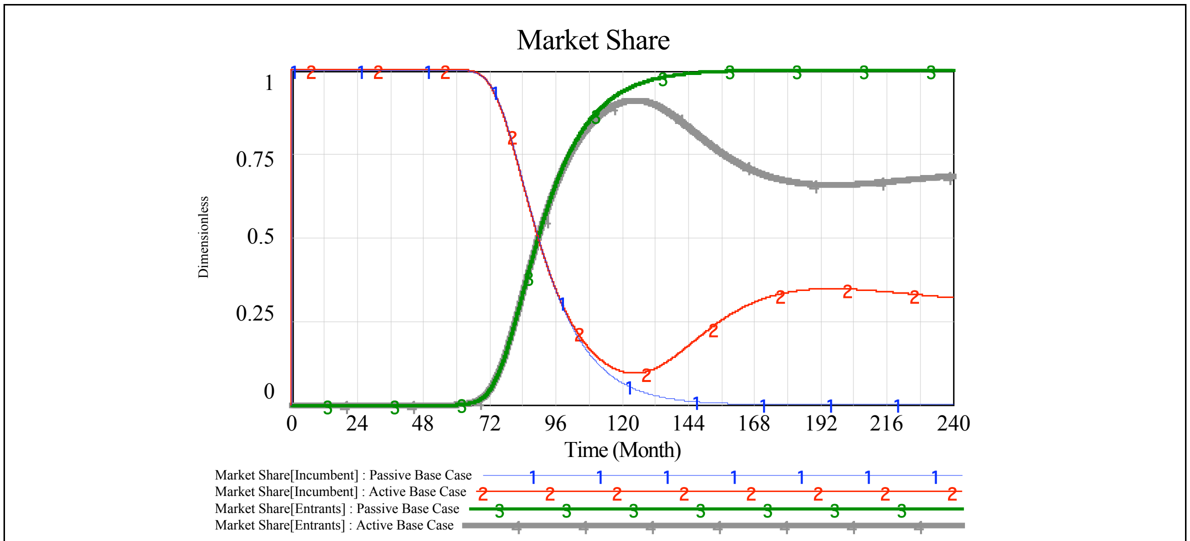

Figure 7 Passive vs. Active Base Case : Market Share

The reason for incumbent's regaining the market share in Active Base Case is the resource reallocation to ancillary performance. This can be seen in Figure 8.

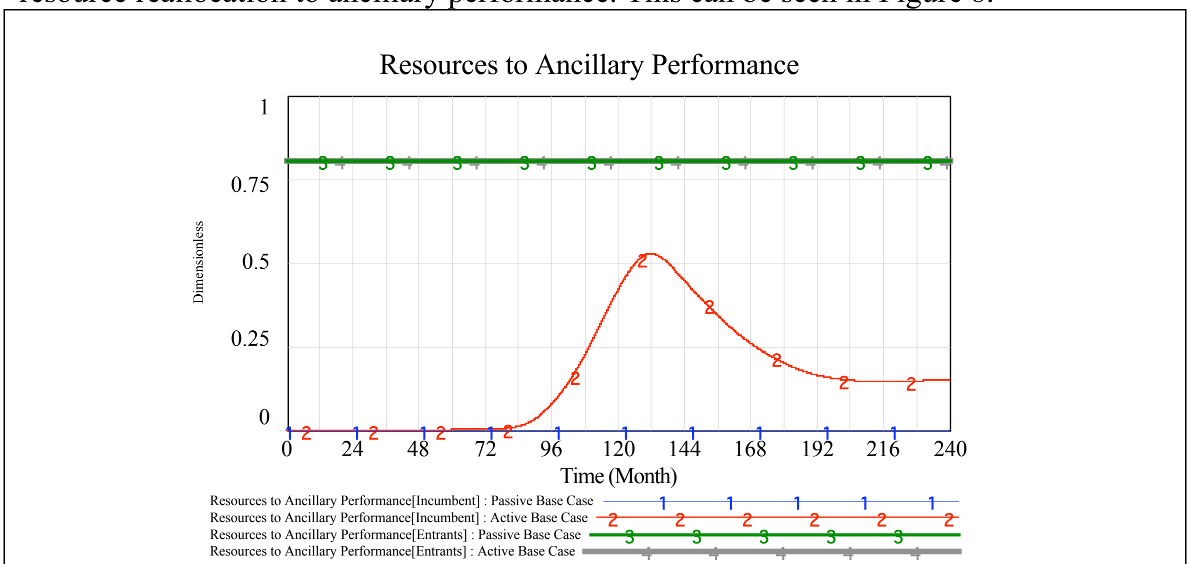

Figure 8 Passive vs. Active Base Case: Resource to Ancillary Performance

Outcome under Uncertainty

We now introduce the three types of uncertainties – technological, market and organizational – to see how the outcome is impacted.

<u>Technological Uncertainty</u>

Performance Acquisition Time for primary and ancillary performance depends on the technological characteristics. Our interviews indicate that the incumbent's slow response to the entrant's expected market share (Figure 5) is typically due to its belief that the entrant will take a long time to catch up with its primary performance. A typical reason for such a belief is that the incumbent has worked long on perfecting the primary features their customers like. To explore the different possibilities, for the time it takes the entrant to catch up with the incumbent's primary performance, we examine the outcome under shorter than expected (1/4th) and longer than expected (4 times) the Primary Performance Acquisition Delay.

Figure 9 shows that if the incumbent was right in its belief, and the Primary Performance Acquisition Delay was indeed long, the incumbent would be able to diversify its resources in time to deliver a product more attractive than the entrant (follow line #3). On the other hand, if the delay was shorter, the incumbent would end up with an adopter base that is even smaller than the Active Base Case (follow line #2).

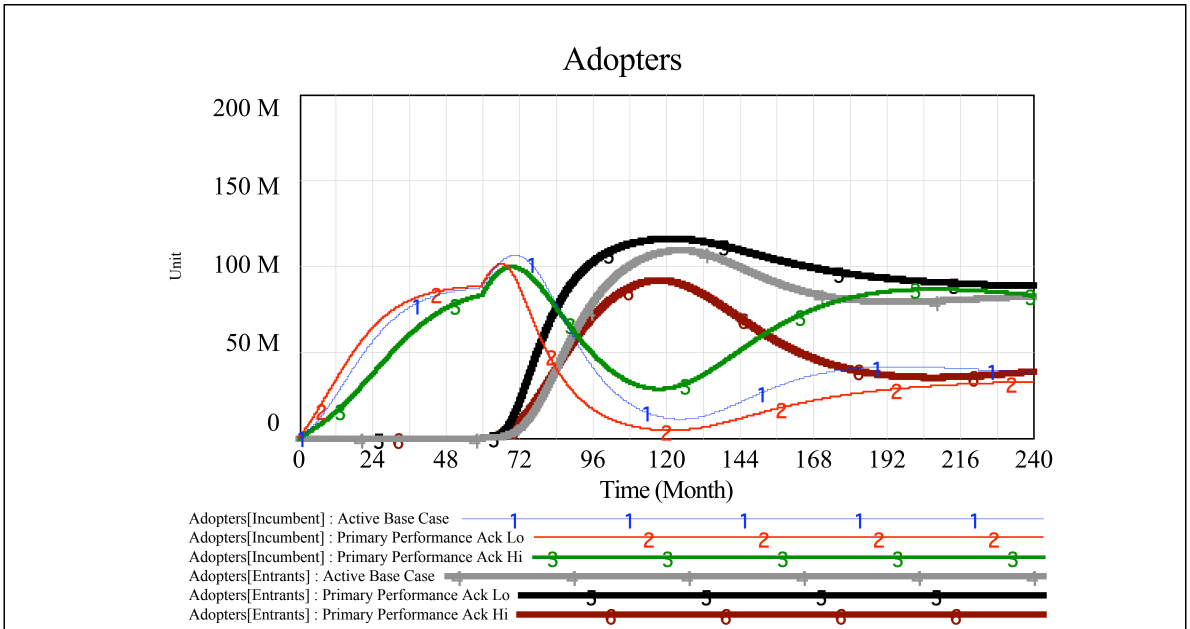

Figure 9 Adoption with uncertain Primary Performance Acquisition Delay

Market Uncertainties

Let us now evaluate the outcomes under two types of market uncertainties – network effect and switching costs.

Network Effect

Direct network effects are present if adoption by different users is complementary, so that each user's adoption payoff, and his incentive to adopt, increases as more others adopt (Fisher and Massachusetts Institute of Technology. Dept. of Economics. 1990). To introduce different network effects we set the Sensitivity of Attractiveness to Installed Base to a low value (0.02) and a high value (0.08). The sensitivity, when set to 0 yields the Active Base Case with no network effect.

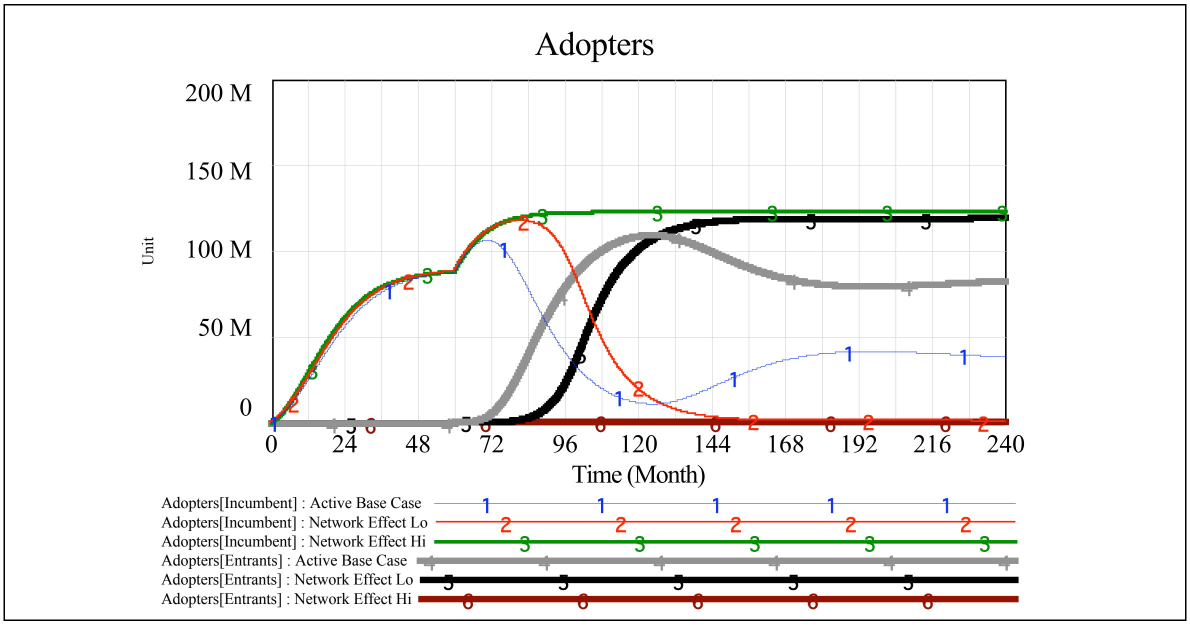

Figure 10 Adoption with uncertain Network Effect

Figure 10 shows the number of adopters under zero, low and high network effect. As illustrated, when the network effects are present, the equilibrium is winner take all (WTA). The strength of network determines who the winner is. When the network effects are weak (low) the entrant snatches the entire market share from the incumbent (follow line #2). Conversely, under strong (high) network effect, the incumbent retains the market (follow line #3).

Switching Costs

A product has classic switching costs if a buyer will purchase it repeatedly and will find it costly to switch from one seller to another. Switching costs arise due to the product characteristics or due to contracts (Fisher and Massachusetts Institute of Technology. Dept. of Economics. 1990). In the Active Base Case, the switching behavior is endogenous and depends on product attractiveness. The more attractive the product the higher are the switching costs, and hence lower is the fraction willing to switch.

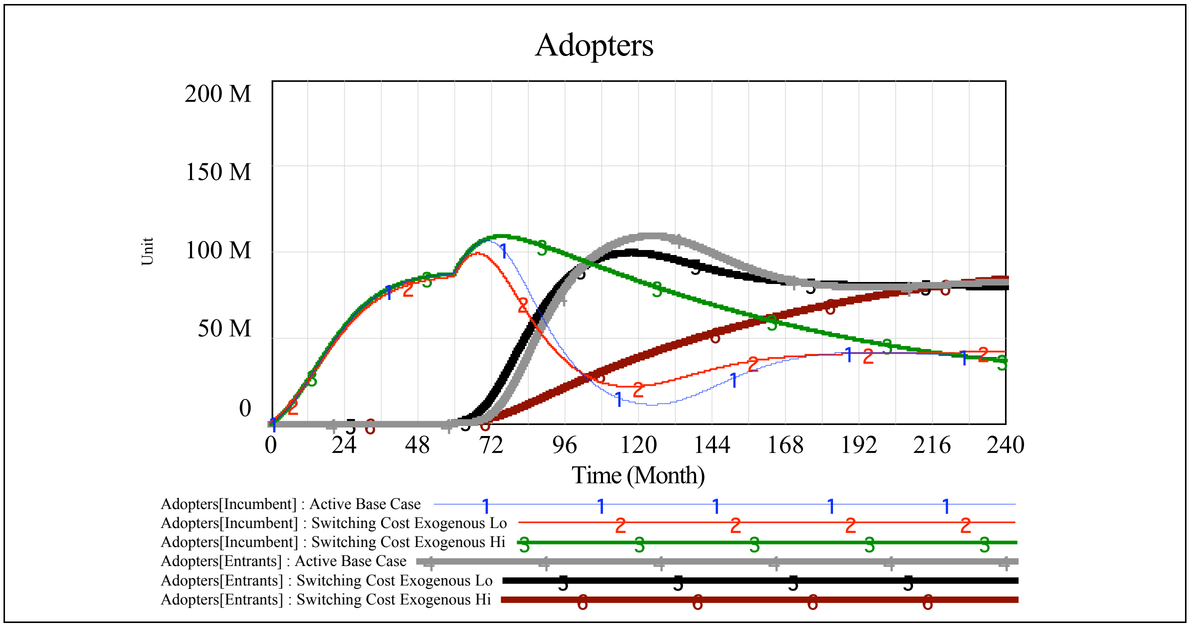

Figure 11 Adoption with uncertain Switching Costs

Figure 11 shows how the number of adopters changes when switching is exogenously induced. Such a case is not hypothetical as firms always lure consumers from competitors through a variety of schemes. The outcome is that the higher the switching costs, the more is the "stickiness" and longer does the incumbent retains the market (follow line #3).

<u>Organizational Uncertainties</u>

The most important organizational uncertainty of interest is how quickly it responds to the threat of disruption. To understand how the outcome changes with the firm's agility, we varied the Resource Reorientation Time uniformly between 1 month and 24 months.

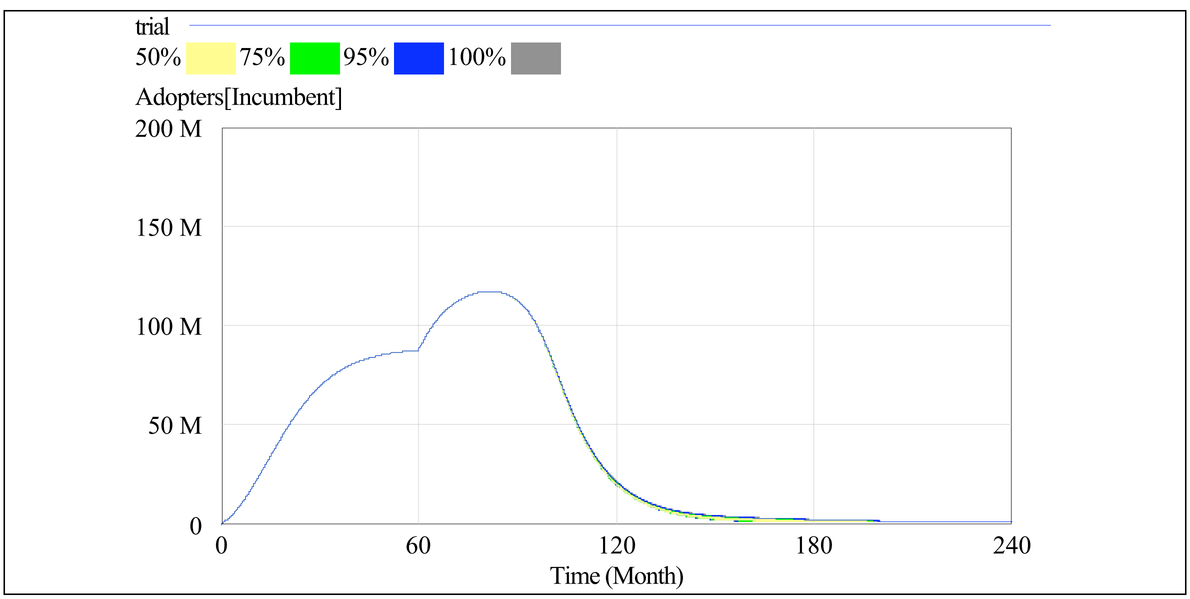

Figure 12 Incumbent's Adoption with uncertain Resource Reorientation Time

Figure 12 shows a somewhat surprising outcome for the number of adopters for the incumbent. The results show that the firm's agility has very little effect on the final outcome. Such a result would argue that the nature of technology and market matter more than the firm's behavior. In our future work we plan to investigate this result further.

DISCUSSION AND CONCLUSIONS

The results above show that technology disruption dues not always mean industry disruption. Figure 13 shows the possible outcomes for the incumbent's market share when all of the aforementioned uncertainties are at work. To carry out this sensitivity analysis, we have assumed that all of the uncertainties – namely technical (primary performance acquisition delay), market (network effect and switching costs), and organizational (resource reorientation time) – vary uniformly over the range specified in the previous section.

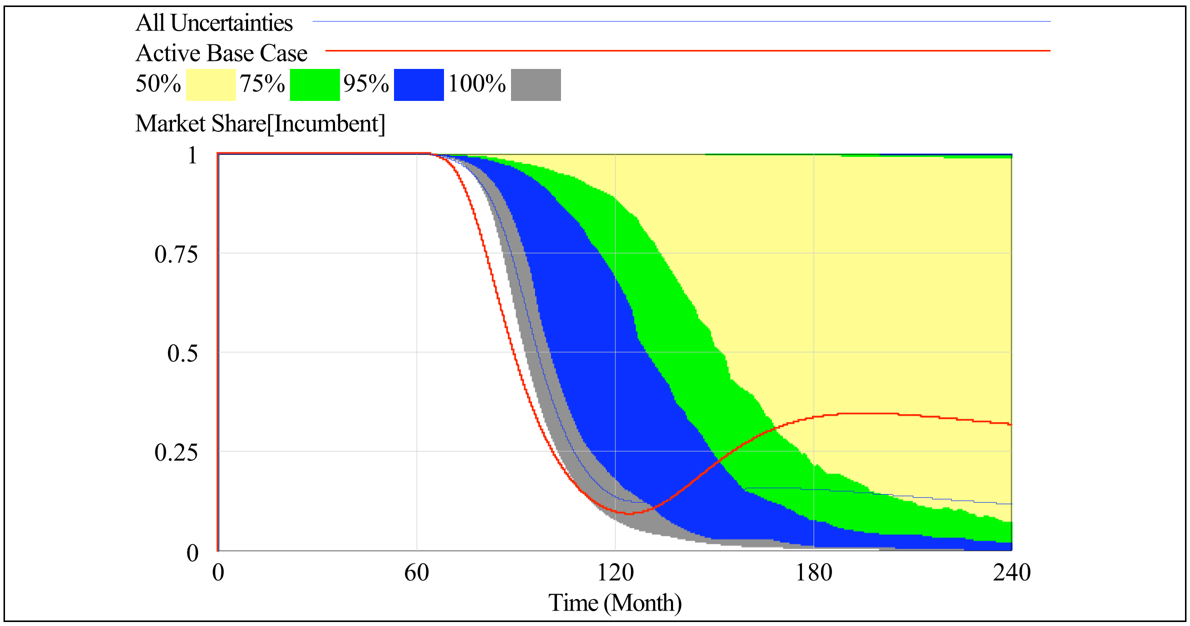

Figure 13 Sensitivity analysis with all of the uncertainties present

<u>Network effect can create a winner take all (WTA) market, and the strength of the network effect can determine the winners and losers</u>

Figure 14 shows the incumbent's final or equilibrium market share for different levels of network effect. This plot is produced by aggregating final outcomes of many runs with different levels of network effect. The plot shows a sudden phase shift in the incumbent's final market share based on the level of network effect, illuminating two regions: (1) a region of weak network effect where the entrant wins, and (2) a region of strong network effect where the incumbent wins. When the network effect is weak, other factors such as lower price and higher ancillary performance give initial advantage to the entrant. By the time the incumbent catches up on the ancillary performance, it is too late, as the entrant already has most of the installed base. Conversely, when the network effect is strong, it has higher influence on product attractiveness than price, performance, or switching costs.

Strong network effect helps the incumbent retain its entire market share as the incumbent already has a large enough installed base to leverage the strong network effect by the time the entrant comes into the market.

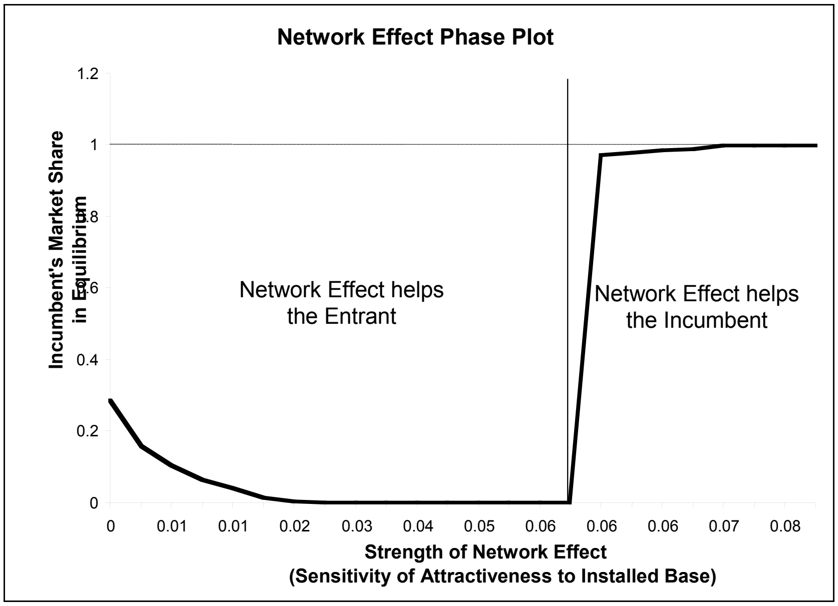

Figure 14 Network Effect Phase Plot for Incumbent's Market Share in Equilibrium

It is not easy to exactly measure the strength of the network effect. What is easier is to detect the presence or absence of it. Also, it is possible to evaluate the different levels of the network effect nominally. In the cases we considered above, incumbent operating systems benefit from strong indirect network effects due to software applications that run on them. The wireless and wireline telecommunications have network effects due to calling plans such as free in-network calling, over and above the direct network effects from building an access network. Entrants of P2P Service are creating strong network effects of their own by offering buddy lists such as the one on Skype or IM. A classic strategy for entrants to neutralize the incumbent's network effect advantage is to make their product interoperate with the incumbent's product.

<u>Higher switching costs lengthen customer retention periods</u>

It may be obvious to state that higher switching costs lead to longer retention of the consumer. However, it is important to understand that a longer customer retention time gives the firm the time to reorient its resources for reacting to competition. The dynamics of retaining consumers by increasing switching costs seems to be quite well understood. Operating systems manufacturers bundle application software to increase switching costs. Wireless operators subsidize handsets and sign multi-year contracts with customers. Cable or broadcast television operators tie up with content providers to offer programming, all in order to increase switching costs. On the entrant side, the most common strategy seen is to offer the service for free, at least initially, to compensate the consumers moving over from the incumbent for the switching costs they bear. For example, services like skype and IM are offered for free.

The natural technology advantage helps the incumbents, not just the entrants

Long primary performance acquisition delay helps the incumbents by giving them the time to reorient resources to respond to entrants. Similarly, long ancillary performance acquisition time helps the entrants. Of the factors that determine how long it takes to master primary or ancillary performance, the nature of technology is the most uncertain. Technological discontinuities arise through stochastic evolutionary processes. While one can select the technology to work on, it is difficult to plan for it. The only observation that we can make about the performance acquisition delays is that in computer and telecommunications industries, reaching the desired level of performance has taken increasingly shorter time than expected. In the cases above, the open source software, WiFi Mesh Networks and P2P Service have taken shorter time to mature than what the incumbents expected[5].

In conclusion, we have identified several conditions under which, despite meeting Christensen's conditions, the entrant technology may not disrupt the existing industrial order. Our work argues for broadening the agenda for research on industry disruption. The general model of industry disruption we offer in this paper is the beginning of such an expansion. The obvious next step is to more broadly validate the model we have offered.

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APPENDIX A

Instructions for Reproducing Experiments

The following section provides instructions on how the various model runs presented in this paper can be reproduced using the submitted model.

Passive Base Case (Figure 6, Figure 7, Figure 8)
Purpose: Incumbent does not respond to the Entrant's market entry.

Variable	Set to Value	Notes
Switch for Passive Base Case	1	
Switch for internetwork externality	1	

Active Base Case (Figure 6, Figure 7, Figure 8)
Purpose: Incumbent diversifies resources as formulated.

Variable	Set to Value	Notes
Switch for Passive Base Case	0	
Switch for internetwork Externality	1	

Performance Acquisition Delay (Figure 9)
Purpose: Outcome when Primary Performance Acquisition Delay is different.

Variable	Set to Value	Notes
Primary Performance Acquisition Delay	Short = 3 Months Long = 48 Months	1/4th 4 times
Switch for internetwork Externality	1	
Switch for Exogenous Switching	1	

Network Effect (Figure 10)
Purpose: Outcome when there are weak and strong network externalities.

Variable	Set to Value	Notes
Sensitivity of Attractiveness to Installed Base	Lo = 0.02 Hi = 0.08	
Switch for internetwork Externality	0	

Switching Cost (Figure 11)
Purpose: Outcome when there are low and high switching costs.

Variable	Set to Value	Notes
Maximum Fraction Willing to Switch	Lo = 0.08 Hi = 0.008	High switching costs corresponds to low faction willing to switch. Low switching costs amounts to 8% consumers switching per month (96% per year). High switching costs mean 0.8% consumers switching per month (9.6% per year)
Switch for internetwork Externality	1	
Switch for Exogenous Switching	1	

Resource Reorientation Time (Figure 12)
Purpose: Outcome when there are low and high switching costs.

Variable	Set to Value	Notes
Resource Reorientation Time	Lo = 1 Month Hi = 24 Month	
Switch for internetwork Externality	1	
Switch for Exogenous Switching	0	

How might the incumbent survive the industry disruption? (Figure 13)
Purpose: Outcome when Maximum Fraction Willing to Switch and Primary Performance Acquisition Delay changes uniformly.

Variable	Set to Value	Notes
Primary Performance Acquisition Delay	RANDOM_UNIFORM Min = 3 Months Max = 48 Months	Use Sensitivity Button on Vensim to setup
Sensitivity of Attractiveness to Installed Base	Lo = 0.02 Hi = 0.08	
Maximum Fraction Willing to Switch	RANDOM_UNIFORM Min = 0.008 Max = 0.08	Use Sensitivity Button on Vensim to setup
Resource Reorientation Time	Lo = 1 Month Hi = 24 Month	
Adopters, Market Share		Set up for variables recording multiple values for sensitivity
Switch for internetwork Externality	1	
Switch for Exogenous Switching	1	